

中国北方桃李间作对步甲群落组成和营养级结构的影响

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摘要:【目的】由于桃树和李树在生态环境要求上很相似, 在生产实际中, 在中国很多地方存在桃李间作或邻作的现象。本研究将通过试验明确桃李间作对步甲营养级结构的影响以便更全面地评价桃李间作是否有利于害虫防治。【方法】2006 和 2007 年的 4–10 月, 在山西省临汾市郊, 通过陷阱法对 3 块桃李间作果园和 3 块单一桃园内的步甲进行抽样, 每块果园的面积约 0.3 hm²。比较两类桃园内步甲物种丰富度。将 6 种优势步甲物种, 两两单一成虫个体组合放在玻璃瓶内, 放在桃树下, 统计步甲相互攻击后的伤亡情况, 比较各物种的相互攻击能力, 确定主要步甲所属的营养级。统计分析两类桃园步甲营养级结构的差异。【结果】桃李间作园和单作桃园调查到的步甲物种均为 24 种, 估测步甲物种数在两类果园的差异也不显著 ($P \geq 0.38$)。6 种优势步甲可以分为 4 个营养级: 大盗步甲 *Lesticus magnus* (Motschulsky) 为高级捕食者, 大锹步甲 *Scarites acutides* Chaudoir 为次级捕食者, 双斑青步甲 *Chlaenius bioculatus* Chaudoir 和躑步甲 *Calathus halensis* (Schaller) 为初级捕食者, 毛婪步甲 *Harpalus griseus* (Panzer) 和直隶婪步甲 *Harpalus tschiliensis* Schauburger 为植食者。各营养级步甲相对多度均是桃李间作果园大于单一桃园, 独立 *T* 检验结果表明, 植食者步甲相对多度差异达极显著水平 ($P \leq 0.002$); 而捕食者步甲相对多度, 除 2006 年初级捕食者步甲相对多度差异显著 ($P = 0.013$) 外, 在调查的两年中其他捕食者营养级步甲相对多度差异均不显著 ($P \geq 0.085$)。【结论】结果表明, 桃李间作对步甲群落的物种组成和丰富度没有影响, 但是对果园内各营养级步甲相对多度有影响, 其中, 对植食者营养级步甲相对多度影响显著, 而对捕食者营养级步甲相对多度影响多不显著。

关键词: 步甲; 桃园; 桃李间作; 群落组成; 营养级; 捕食能力

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Effect of plum-peach intercropping on community composition and trophic structure of carabids (Coleoptera: Carabidae) in North China

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Abstract: 【Objective】There are many plum-peach intercropping or neighboring orchards in many regions in China due to their similar ecological environments. The experiment was carried out to clarify the effect of plum-peach intercropping on trophic structure of ground beetles, and to assess whether plum-peach intercropping is beneficial to pest control. 【Methods】Ground beetles were investigated with pitfall trapping method in three mono-peach orchards and three plum-peach intercropping orchards in Linfen, Shanxi from April to October in 2006 and 2007, of which each experimental orchard is about 0.3 hm². The Carabidae species richness was compared between the two kinds of orchards. For the six dominant Carabidae species determined, two different species in combination were placed in one glass bottle with 10 beet webworms as food, and the bottles were placed under peach trees. The results of beetle attacking recorded from these bottles were used to determine the trophic level of Carabidae species. The relative abundances of carabids from each trophic level were compared between the two kinds of orchards. 【Results】The 24 species of ground beetles were found, and the number of species showed no significant difference between in mono-peach orchard and in plum-peach intercropping orchard ($P \geq 0.38$). In addition, the six dominant species could be classified into four trophic levels: *Lesticus magnus* (Motschulsky) belongs to the senior predator, *Scarites acutides* Chaudoir the intermediate predator, *Chlaenius bioculatus* Chaudoir and *Calathus halensis*

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(Schaller) junior predators, and *Harpalus tschiliensis* Schaubberger and *Harpalus griseus* (Panzer) herbivores. The relative abundance of carabids at different trophic levels was higher in plum-peach intercropping orchard than in mono-peach orchard. The results of *T* test showed that extremely significant difference ($P \leq 0.002$) and significant difference ($P = 0.013$) in relative abundances of herbivores and junior predators existed between the two kinds of peach orchards in 2006, respectively, but no significant difference ($P \geq 0.085$) in relative abundance existed in carabids of other trophic levels in the surveyed two years. 【Conclusion】 It is concluded that plum-peach intercropping has no effect on the species component and richness of the ground beetles in the plum-peach intercropping orchard, but has some effects on population relative abundance of different trophic levels in the ground beetles. In general, plum-peach intercropping has significant effects on carabid abundance at different trophic levels of herbivores, but has no significant effect on carabid abundance at most trophic levels of predators.

Key words: Carabids; peach orchard; plum-peach intercropping; community composition; trophic level; preying ability

步甲在昆虫群落当中是一个特殊的群体,既不是农业生产当中的主要害虫,也不是害虫防治中的生物防治开发对象,然而却受到科学工作者们的广泛关注。这主要是由于步甲的两个主要特点:1)大多数步甲都是广食性肉食者,人们希望发现步甲的生物防治价值(Menalled *et al.*, 1999; Symondson *et al.*, 2002; 胡雅辉等, 2006; Thomas *et al.*, 2009); 2)步甲物种丰富,分布广泛,且对环境敏感,人们常用步甲群落的特征判断农业措施的好坏(Carcamo *et al.*, 1995; Glen, 2000; Epstein *et al.*, 2001; Rainio and Niemelä, 2003)。目前,由于桃树和李树在生态环境要求上很相似,桃李间作或邻作在中国很多地方存在,然而桃李间作的合理性却没有被广泛地评价。胡雅辉等(2009)研究了桃李间作对桃树上节肢动物的影响,认为桃李间作会增加山楂叶螨 *Tetranychus viennensis* Zacher 的危害程度。为了更全面地评价桃李间作的优劣,本文开展了桃李间作对步甲影响方面的研究。

一些研究农业措施对步甲影响的结论表明:步甲物种丰富度很少受到农业措施的影响,但是步甲群落中的一些物种的种群数量容易受到各种农业措施的影响(Vanbergen *et al.*, 2010)。由一些物种种群数量的减少或增多导致步甲群落多样性指数的变化到底指示什么,却存在着许多争议,大多数研究者认为步甲群落多样性高表示该种农业措施值得提倡,这在一些很明显的例子中得到了证实(Clark, 1999; Shah *et al.*, 2003),但是也有研究表明步甲群落多样性代表的是不好的农业措施(Clark *et al.*, 2006)。当常规的生态学指标:步甲物种丰富度、个别步甲物种种群密度和多样性指数难以指示农业措施的好坏时,我们需要对不同农业措施情况下步

甲群落的差异作更细致的分析。然而由于步甲物种的丰富性,农业措施对步甲密度的影响在步甲各物种上是不对称的,又由于步甲食性的多样化,这种不对称的影响体现在不同营养级的步甲密度格局产生变化。基于害虫治理的目的,分析一种农业措施对步甲群落营养级结构的影响,成为步甲群落评判的一个重要内容。

1 材料与方法

1.1 试验地概况

试验地选择在山西临汾市郊区,该地位于111.51°E, 36.08°N,属于大陆性气候,年平均温度10.7℃,最低温-4℃在1月,最高温26℃在7月,年降雨量是555 mm,无霜期180 d。该地属于平原地区,所选果园1998年以前是小麦种植区。

根据实验对比需要,选择3块桃李间作果园和3块单作桃园,邻近果园之间的距离大于600 m,每片果园约0.3 hm²。桃李间作果园为布朗李和久保桃品种间作,1行桃树1行李树相间排列,桃树行和李树行相距2.5 m,株距1 m。单作桃园的桃树品种也为久保,栽植密度为1 m×2.5 m。所有果园均施行统一管理,每年修剪3次,分春剪、夏剪和冬剪,所选果园杂草覆盖情况比较一致,无人工种植的作物,单一桃园每年行间耕翻2次以除草,桃李间作果园采用圆盘割草机除草,4月进行疏果,试验期间除阿维菌素外不施用其他杀虫剂,从4月起悬挂糖醋液、主要害虫苹小卷叶蛾 *Adoxophyes orana* (Fischer von Röslerstamm) 和梨小食心虫 *Grapholitha molesta* (Busck) 两种性诱芯诱杀害虫。

1.2 陷阱设置及抽样

以双层塑料口杯(直径10 cm,高12 cm)作为

表 1 2006 和 2007 年两类桃园的步甲物种数估算值
Table 1 The estimated species of carabids in two kinds of orchards in 2006 and 2007

估测方法 Estimation methods	桃李间作园 Plum-peach intercropping orchard	单一桃园 Mono-peach orchard	<i>T</i> 检验中的 <i>P</i> 值 <i>P</i> value in <i>T</i> test
Bootstrap	22.8	21.8	0.38
Jackknife	24.5	23.8	0.70
Chao-2	22.2	23.1	0.74

2.2 步甲营养级结构

取食研究表明,任一组合都没有捕食完所有的甜菜野螟幼虫,即在步甲不缺少食物的情况下,大盗步甲 *L. magnus* 能够攻击致死所有别的步甲(表 2)。毛婪步甲 *H. griseus* 和直隶婪步甲 *H.*

tschiliensis 不能攻击致死其他的步甲(表 2)。躅步甲 *C. halensis* 仅被大盗步甲攻击致死,同时它能攻击致死另外的 4 种步甲。躅步甲 *C. halensis* 和双斑青步甲 *C. bioculatus* 能被大锹步甲 *S. acutides* 和大盗步甲 *L. magnus* 攻击致死,同时它们也能攻击致死毛婪步甲 *H. griseus* 和直隶婪步甲 *H. tschiliensis*。除了毛婪步甲和直隶婪步甲,其他 4 种步甲物种都取食甜菜野螟,可见毛婪步甲和直隶婪步甲为植食性的,其他的 4 种步甲都是肉食性的。总之,这几种常见的步甲根据其相互攻击能力大小可以分为 4 个营养水平:大盗步甲 *L. magnus* 为高级捕食者,大锹步甲 *S. acutides* 为次级捕食者,双斑青步甲 *C. bioculatus* 和躅步甲 *C. halensis* 为初级捕食者,毛婪步甲 *H. griseus* 和直隶婪步甲 *H. tschiliensis* 为植食者。

表 2 6 种步甲两两组合时被杀死的步甲物种及甜菜野螟幼虫死亡数
Table 2 Killed carabid species and number of beet webworm larvae when 2 species of carabids were combined

	C		大盗步甲 <i>Lesticus magnus</i> (Motschulsky)	躅步甲 <i>Calathus halensis</i> (Schaller)	大锹步甲 <i>Scarites acutides</i> Chaudoir	双斑青步甲 <i>Chlaenius bioculatus</i> Chaudoir	毛婪步甲 <i>Harpalus griseus</i> (Panzer)	直隶婪步甲 <i>Harpalus tschiliensis</i> Schauberger
	C	S						
大盗步甲 <i>L. magnus</i>			—	6	7	6	7	7
躅步甲 <i>C. halensis</i>		躅步甲 <i>C. halensis</i>		—	4	5	6	5
大锹步甲 <i>S. acutides</i>		大锹步甲 <i>S. acutides</i>		大锹步甲 <i>S. acutides</i>	—	3	4	4
双斑青步甲 <i>C. bioculatus</i>		双斑青步甲 <i>C. bioculatus</i>		双斑青步甲 <i>C. bioculatus</i>		—	2	2
毛婪步甲 <i>H. griseus</i>		毛婪步甲 <i>H. griseus</i>		毛婪步甲 <i>H. griseus</i>	毛婪步甲 <i>H. griseus</i>	毛婪步甲 <i>H. griseus</i>	—	—
直隶婪步甲 <i>H. tschiliensis</i>		直隶婪步甲 <i>H. tschiliensis</i>		直隶婪步甲 <i>H. tschiliensis</i>	直隶婪步甲 <i>H. tschiliensis</i>	直隶婪步甲 <i>H. tschiliensis</i>	—	—

C: 放入瓶里的步甲物种 Carabidae species placed into glass bottle; N: 被杀死的甜菜野螟幼虫数量 Number of beet webworm larvae killed; S: 被杀死的步甲物种 Carabidae species killed.

2.3 不同营养级步甲相对多度差异

独立 *T* 样本检验结果表明,在 2006 年和 2007 年 4 个营养级步甲相对多度,桃李间作果园均大于单作桃园,其中,2006 年和 2007 年植食者营养级步甲相对多度两类桃园之间差异极显著,2006 年初级捕食者营养步甲相对多度两类桃园之间差异显著,其他年度其他营养级步甲相对多度两类桃园间差异不显著(表 3)。

3 讨论

有研究认为随着标本数量的增多,被调查到的

步甲物种数量也在上升,直到接近一个极限值 (Gotelli and Colwell, 2001),当接近一个极限值时,可以根据调查到的步甲物种数来推断整个生境内步甲的物种数量,本实验中两类桃园抽样到的步甲物种数都各自达到了一个恒定值(图 2),表明可以通过抽样得到的步甲标本来估测整个果园内步甲的物种数。节肢动物群落的物种丰富度通常会受到地面植被种类的影响 (Woodcock et al., 2009),然而,步甲物种在桃李间作园和单作桃园却没有显著差异,均属于中国北部本地常见步甲物种,这些步甲物种也在其他的作物如棉花、小麦、玉米、苜蓿生境内

表 3 两类桃园不同营养级步甲相对多度

Table 3 The relative abundance of different trophic levels of carabids in two kinds of peach orchards

步甲营养级 Trophic level	年份 Year	桃李间作园 Plum-peach intercropping orchard	单一桃园 Mono-peach orchard	P
植食者 Herbivore	2006 **	926.0 ± 30.0	198.3 ± 14.5	0.000
	2007 **	542.3 ± 39.6	200.7 ± 24.7	0.002
初级捕食者 Junior predator	2006 *	158.7 ± 11.7	92.0 ± 10.6	0.013
	2007	360.3 ± 85.3	256.3 ± 75.1	0.412
次级捕食者 Intermediate predator	2006	56.3 ± 7.8	76.3 ± 13.1	0.085
	2007	29.3 ± 3.5	27.0 ± 8.7	0.689
高级捕食者 Senior predator	2006	47.0 ± 25.5	40.7 ± 19.9	0.752
	2007	41.3 ± 14.2	10.7 ± 5.0	0.102

同一营养层步甲相对多度为每个果园全年所有陷阱收集到的同类步甲的数量 The relative abundance of carabids of a trophic level denotes the number of carabids of a trophic level in each peach orchard in one year . * 该年度该营养级两类桃园之间步甲相对多度独立显著值 $P \leq 0.05$ (T 检验) Relative abundance of carabids belonging to the same trophic level between two kinds of orchards in this year showed significant difference ($P \leq 0.05$, T test); ** 该年度该营养级两类桃园之间步甲相对多度独立显著值 $P \leq 0.01$ (T 检验) Relative abundance of carabids belonging to the same trophic level between two kinds of orchards in this year showed significant difference ($P \leq 0.01$, T test).

被发现(刘云慧等, 2004; 谷卫彬等, 2004; 胡雅辉等, 2006)。除作物间作外, 其他的农业措施也只影响步甲的密度, 但是不会改变步甲的物种(Ekroos *et al.*, 2010; Vanbergen *et al.*, 2010)。步甲物种不随农业措施的改变而改变可以归因于大多数的步甲物种都能适应多种生境和食物。例如, 步甲的活动性就被证明不仅仅局限于地面, 一些植食性的步甲物种雌性成虫会爬树寻觅食物, 而雄性成虫则爬树寻找雌性进行交配(King *et al.*, 2010); 对特定捕食步甲提供多种可替代的食物, 能够减少猎物的被捕食压力, 猎物种群密度显著上升(Frank *et al.*, 2010), 表明步甲能适应习惯食物以外的其他食物。

桃李间作果园较单作桃园的植被更加多样化, 为步甲提供了更多的生境选择, 增加了大多数步甲的相对多度, 前人的研究也表明, 多样化的作物往往较单一作物更有利于步甲(Carcamo *et al.*, 1995)。我们的研究表明, 桃李间作对植食者营养级步甲相对多度影响显著, 而对捕食者营养级步甲相对多度的影响则多不显著。我们推测包括桃李间作在内的地面植被景观对植食性步甲具有直接的影响, 其他营养级步甲通过捕食关系也会受到一致的影响, 当猎物密度增加时, 将促进捕食者密度增长, 反之亦然。但是捕食者营养级的步甲是否也受到了生境不同的直接影响却难以判断, 原因在于两个方面: 一是营养级金字塔生物数量递减的关系, 即使较高营养级步甲受到了和低营养级一样程度的直接影响, 在统计结果上也可能存在差异不显

著的现象; 二是由于步甲群落内部复杂的食物链关系, 同位素标记研究表明, 处在较高营养级的多种步甲捕食者消费着较低营养级同样的猎物, 但是量可能存在差异, 可见步甲捕食者食性较广, 同时不同的捕食者又存在自己的食物喜好(Okuzaki *et al.*, 2010), 而且当不同的步甲遭遇时, 不同的步甲物种将会相互攻击, 当同一步甲捕食者密度过大时, 甚至出现同类相残(Frank *et al.*, 2010)。虽然增加捕食者的步甲密度已经表明可能增强或消减对猎物的压力(Straub and Snyder, 2006), 然而由于不同生境较高营养级步甲密度差异不显著, 因此, 对较低营养级步甲密度产生的影响是有限的。

不同地区步甲优势种可能不一样, 用优势物种代表同一营养级步甲探讨桃李间作对步甲营养级结构的影响, 也许值得商榷, 然而类似的研究结果有: 一个欧洲尺度范围内的景观生态研究也表明, 较低营养水平(植食性)的步甲密度与植被景观密切相关, 而较高捕食营养水平的步甲密度受到的影响则较少(Vanbergen *et al.*, 2010)。可见, 桃李间作对植食者营养级步甲密度确实有显著增加的影响, 而对捕食者营养级步甲密度的影响一般不显著。

总之, 由于步甲食性既广又有各自的偏好, 同一营养级捕食性步甲会相互攻击的特点, 目前难以评判桃李间作园步甲营养级结构较单作桃园是否对潜在的害虫更具压力, 需要在未来的研究中更进一步的明确主要步甲对特定害虫的喜好。

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